DUPLEX CAMERA PORTABLE MOTION CAPTURE SYSTEM FOR SINGLE ATHLETE'S PERFORMANCE ANALYSIS

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ABSTRACT

In recent years, introduction of depth camera in motion capture have caught a massive attention by both researchers and biomechanists. Therefore, high-performance sports certainly require motion capture technology to compete with other competitors. Thus, a study involving quantitative analysis is important to obtain a more accurate analysis. The purpose of this study is to develop duplex motion capture system for biomechanical analysis of sports. The visual sensor used in this research consists of two Kinect sensors Microsoft. The case studies were focused on a single athlete for sepak takraw pre-serve and bunga silat at any single time. MATLAB and Software Development Kit (SDK) by Microsoft were used as software developing platform. Accuracy between software developed in MATLAB platform and SDK were compared and the best platform in term of performance and accuracy were chosen. "Bunga silat" in Silat and sepak takraw pre-serve were chosen as the case studies to justify the feasibility of the system. This study also examined the capability of Kinect Xbox 360° sensor and software to be used in biomechanical analysis. Result obtained revealed significant achievement in terms of motion capture system in the biomechanical analysis on certain sports. For Sepak Takraw, the foot-to-foot distance and angle of knee before serve has been used as a parameter to determine the speed of the ball to be serviced. In this research the highest ball speed recorded is 69km/h with 1.0664m of foot-to-foot distance and 147.20° of right knee 153.52° for the left knee at the pre-serve phase. Whereas for Silat, it shows that the amateur motion is very much similar from the practitioners. The closer the mean and standard deviation value to unity the more accurate the movement referred to the benchmark stated. Therefore, to increase the accuracy of movement execution, the subject needs to repeat the movement execution until perfection which is set by the teacher. In summary, this research successfully described an athlete's performance quantitatively using motion capture system.

ABSTRAK

Dalam tahun kebelakangan ini, pengenalan kamera kedalaman dalam penangkapan pergerakan telah menarik perhatian besar para penyelidik dan biomekanik. Oleh itu, sukan berprestasi tinggi memerlukan teknologi menangkap gerakan untuk bersaing dengan pesaing lain. Kajian yang melibatkan analisis kuantitatif adalah penting untuk mendapatkan analisis yang lebih tepat. Tujuan kajian ini adalah untuk membangunkan sistem tangkapan gerakan jenis dupleks untuk analisis biomekanikal terhadap sukan. Visual pengesan yang digunakan dalam kajian ini terdiri daripada dua Pengesan Kinect Microsoft. Kajian kes difokuskan pada atlet tunggal untuk pra-servis sepak takraw dan bunga silat pada satu-satu masa. MATLAB dan Kit Pembangunan Perisian (SDK) oleh Microsoft telah digunakan sebagai platform pembangunanan perisian. Ketepatan antara perisian MATLAB dan SDK telah dibandingkan dan perisian terbaik dari segi kualiti dan ketepatan telah dipilih. "Bunga silat" dalam Silat dan sepak takraw pra-servis dipilih sebagai kajian kes untuk membenarkan kelayakan sistem ini. Kajian ini juga menilai keupayaan pengesan Kinect Xbox 360° dan perisian untuk digunakan dalam analisis biomekanik. Keputusan yang diperolehi menunjukkan pencapaian yang ketara dari segi sistem tangkapan pergerakan dalam analisis biomekanik pada sukan tertentu. Untuk Sepak Takraw, jarak kaki dan sudut lutut sebelum melakukan servis telah digunakan sebagai parameter untuk menentukan kelajuan bola untuk diservis. Kelajuan bola tertinggi yang direkodkan adalah 69km/j dengan jarak 1.0664m kaki ke kaki dan 147.20 ° lutut kanan 153.52 ° untuk lutut kiri pada fasa pra-servis. Nilai min untuk kelajuan bola ialah 57.2km/j. dan penyimpangan standard adalah 8.87km/j. Silat pula menunjukkan bahawa gerakan dari amatur sangat mirip dengan para pengamal. Lebih dekat nilai min dan nilai sisihan piawai untuk perpaduan lebih tepat pergerakan merujuk kepada tanda aras yang dinyatakan. Oleh itu, untuk meningkatkan ketepatan pelaksanaan pergerakan, subjek perlu mengulangi pergerakan hingga sempurna seperti yang ditetapkan oleh jurulatih. Ringkasnya, penyelidikan ini berjaya menggambarkan prestasi atlit secara kuantitatif

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LIST OF SYMBOLS AND ABBREVIATIONS

3D	-	Three-dimensional
ACL	-	Anterior cruciate ligament
APIs	-	Application program interfaces
FOV	-	Field of view
Fps	-	Frame rate per second
GUI	-	Graphical user interface
ICP	-	Iterative closest point
IDE	-	Integrated development environment
km/h	-	Kilometer per hour
m	-	Meter
MATLAB	-	Matrix laboratory
SDK	-	Software Development Kit
PaA	-	Plug-and-Access
UTHM	-	Universiti Tun Hussein Onn Malaysia
V1	-	Version 1
V2	-	Version 2

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CHAPTER 1

INTRODUCTION

1.1 Overview

Recently, biomechanical analysis is applied in many applications especially in biomedical, rehabilitation, sports and ergonomics. Such analyses are proven resulted in great impact on sports researches. Advance in sports science has achieved remarkable results in recent years. In athletics for instance, biomechanical analysis via biomechanical technology using imaging technology has succeeded in producing world champion athletes. (Curran & Frossard, 2012).

Biomechanics is an application of mechanical laws to living structure, specifically to human locomotion system (Garner, 2003). Biomechanics branches out from the root words; *bio* which means life or living organisms and mechanics which means the study of the action of forces on particles and mechanical systems. The biomechanics role in life is to grasp the concept of mechanical cause-effect relationships that determine the living organism's motion. Biomechanical analysis is used for maintaining physical functions, improving musculoskeletal health, improving mobility, product design and forensic biomechanics.

Sports biomechanics is a branch of biomechanics that underlines the comprehension of athlete's motion in sporting event through measurement, mathematical modeling and simulation. In sports, analysis is important to improve the performance of an athlete in a sport that they are best at. For an example, a football player shall precisely kick a ball in order to get the ball into a direction that he wanted by analyzing his body movement. Such analysis was made by applying biomechanics

understanding to the action which then to enhance and improve athlete's performance. With biomechanical analysis, analysts, coaches and trainers are able to improve athlete's performances and as well may reduce the probability of injuries and also improve rehabilitation.

1.2 Background of Study

The purpose of this study is to develop duplex motion capture system for sports biomechanical analysis. The visual sensor used in this motion capture system consists of two duplex Kinect sensors. It is where 'duplex' term is originally used.

Duplex Kinect sensor with in-house developed algorithm makes quantitative analysis possible. To produce the best analysis, accuracy between software developed in MATLAB platform and Software Development Kit (SDK) by Microsoft have been considered.

This study is intended to improve sports performance by the used of this developed motion capture system. "Bunga silat" in Silat and *sepak takraw* pre-serve were chosen as the case studies to justify the feasibility of this system. For *sepak takraw*, the motion analysis will provide the guide towards better pre-serve technique in order to improve athlete's performance while serving the ball. At the end of this study, the result obtained may provide improvement solution in the form of physical motion and increasing the effectiveness of *Sepak takraw* serve. The kinematic data analysis will describe the motion technique at pre-serve phase. In addition, this study also examined the capability of Kinect Xbox 360° sensor and software to be used in biomechanical analysis.

1.3 Problem Statement

The Ministry of Youth and Sports (Malaysia) has a mission to bring national sports to the highest level. In modern sports, sport sciences have significantly contributed to the top-class athletes. In recent years, introduction of depth camera used in motion capture have caught a massive attention by both researchers and biomechanists. In the past, such technology was not an option equipment in assisting the achievement of athletes, but now it is the opposite scenario. Therefore, the high-

performance sports certainly require motion capture technology to compete with others competitors.

Thus, a study involving quantitative analysis is important to obtain a more precise and accurate analysis. The existing commercially motion capture systems however have very limited features and not dedicated for the needs of our local athletes. The technology require markers to be attached on subject‘s body. Hence, physical movement is interrupted. In contrast, this research focused on the use of depth cameras as capturing sensor which does not involve markers. The Kinect sensor offers new perspectives for the development and application of affordable, portable and easy-to-use marker-less motion capture (MMC) technology. Although there have been some previous works done on biomechanical analysis using only single Kinect sensor, occlusion and self-occlusion tracking problems incurred. With the usage of duplex Kinect sensors, the mentioned limitation could be significantly reduced.

1.4 Objectives

This project embarks the following objectives:

i. To complete a duplex depth camera motion capture system for sports biomechanical analysis.
ii. To build biomechanics motion analysis software using MATLAB coding platform and (Software Development Kit) SDK.
iii. To prove the performance of the developed biomechanics motion analysis software via study on individual athlete in *sepak takraw* and silat.

1.5 Scope

The scope of this study

i. Duplex Kinect Sensor by Microsoft is used as the motion sensor.
ii. Only individual athlete is analyzed at any single time.
iii. MATLAB coding platform and SDK are used as data capturing tools.
iv. "Bunga Silat" technique in *Sepak Takraw Tekong* and silat are used as sample case studies for biomechanical analysis.

1.6 Significance of Study

Another substantial feature of the Kinect sensor is that it does not required any marker to be attached to the subject – a marker-less motion capturing system. The Vicon system usually used in motion capture technology in contrast requires reflective markers to be attached on the subject's body, the time spent on attaching the markers to the subject is definitely not an advantage. Thus, with the use of duplex Kinect sensor, it could facilitate the set-up process and phase out complex equipment set-up. Besides, the size of the duplex motion capture system increases the portability and mobility as compared to lab based system such as Vicon. The fast, low cost, portable system for capturing these biomechanical measures would facilitate the biomechanists or researchers to bring their work task to the athlete instead of bringing the subject into the lab. This will bring the research work to a whole new advanced level of the way biomechanical analysis is done.

After the motion data extracted from the system, biomechanics analysis is used to assess the performance of athletes in order to gain a greater understanding of human movement. Thus, appropriate quantitative solutions could be developed to improve athlete's techniques and thereby increase the performance, minimizing injuries and in turn, promoting career longevity.

A biomechanics researcher uses quantitative biomechanical analysis methods to discover new techniques, which communicated to the teachers and coaches who will implement them (McGinnis, 2013).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The purpose of this chapter is to review on previous studies that had been accomplished among other researchers in order to obtain more information that related to this project. It is important to study the existing research on biomechanical analysis within motion capture system. By reviewing the previous thesis, journals, articles and reports, considerably it provides important knowledge and information to this project.

2.2 Biomechanics

Biomechanics is the branch of science concerned with comprehension of the interrelationship of structures and functions of living beings, with referring to the kinetics and kinematics of motion (Adrian & Cooper, 1995). With the two components, kinematics and kinetics, the study can yield intensive comprehension on the factors affecting human body at rest or in motion. Biomechanics involves many other scientific disciplines. In order to fully comprehend human movement, the association of aspects like the study of work and energy in physics, forces and moments in mechanical engineering, and neuromuscular connections from biology is needed.

In specific, sport biomechanics study the effects of forces and motion mainly on sport performance. According to Bartlett (2007), sport biomechanics could be briefly defined as “the study and analysis of human movement patterns in sport”. Once

the movement patterns of an athlete is determined, coaches can analyze the sport movements of the athlete, select the best training exercises for him or her, in the meantime reduce or prevent the possibilities of injuries, as well as design or choose the sport equipment that best matches athletes' personal needs and eventually maximize economy and efficiency of movements. The use of technology makes it possible for coaches to provide the athletes with best possible opportunities to achieve maximal performance (Adegbesan & G.A., 2004)

2.2.1 Kinematics and Kinetics Motion

Kinematic describes motion, including the pattern and speed of movement sequencing by the body segments, which often translate to the degree of coordination an individual display, while kinetic study the actions of forces associated with motion (Hall, 1999).

Sport kinematics analysis studies the positions, angles, velocities and accelerations of body segments and joints during motion, while kinetic analysis studies forces that produce the movement (Hay, 1993).

In brief, kinematics are a description of movement and do not consider the forces that cause that movement and the study of kinetics begins to answer the ‘how and why’ of the observed movement. However, as defined in the scope of study, only the kinematics motions of subject were analyzed in this research work.

2.3 The Concept of Biomechanical Analysis

Biomechanical analysis is the evaluation of motion analysis techniques (Adrian & Cooper, 1995). Biomechanical analysis in sports involves both qualitative and quantitative analysis. When it comes to the sport biomechanics, it could be divided into three: qualitative; semi-quantitative and; quantitative analysis. Semi-quantitative mostly is the combination of qualitative analysis and some basic and common measurements, for example, joint angle of a motion, notation – goals scored, passes, etc.

2.3.1 Qualitative Analysis

Qualitative analysis depicts movements in non-numerical way, by expressing any movements as ‘patterns’. Such analysis might appear to be very subjective due to the described ‘data’. Thus, the reliability and accuracy of such data is very subjective especially when it is obtained in a competition. This type of analysis is applied more in structured and multidisciplinary approach (Bartlett, 2007). Qualitative analysis can only be provided successfully by individuals who have an excellent understanding of the specific sport or exercise movements and who can cooperate with a particular client group. Such cooperation requires a positive, ongoing commitment by the individuals involved (Payton & Bartlett, 2008). Qualitative analysis itself consists of four ‘principles’ proposed by several authors. The four methods are:

i. Categorizing movement by its function;
ii. Core notion of kinesiology;
iii. Movement principles approach and;
iv. Comprehensive approach to qualitative analysis

However, it is widely known that the most convincing approach in qualitative analysis of sports biomechanics is the comprehensive approach which was proposed by Knudson and Morrison (2002) as shown in Figure 2.1.

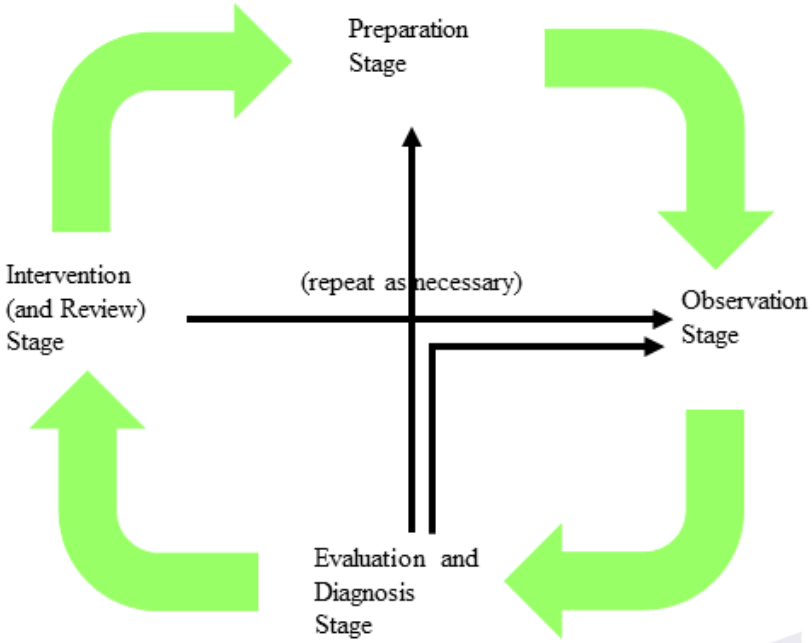

Figure 2.1: Comprehensive methods to qualitative analysis (Bartlett, 2007).

2.3.2 Quantitative Analysis

Quantitative analysis describes and analyses movement numerically and can appear to lack a theoretical grounding and to be data-driven (Bartlett, 2007). The information required in this type of analysis involved variables such as linear and angular displacements, velocities, accelerations, forces, torques, energies and powers; these may be used for detailed technical analysis of a particular movement. Increasingly, sport and exercise biomechanics are looking at continuous time-series data rather than discrete measures (Payton & Bartlett, 2008).

The advantages of using quantitative analysis is that it enables biomechanists to obtain lots of biomechanical data besides the fact that its reliability and objectivity can be easily assessed. In this research work, quantitative analysis was used to asses an athlete's motion and performance. Though this type of analysis involved the usage of expensive equipment and software and more lab-based, this research however aims to allow biomechanical analysis to be done at low cost and high in portability.

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